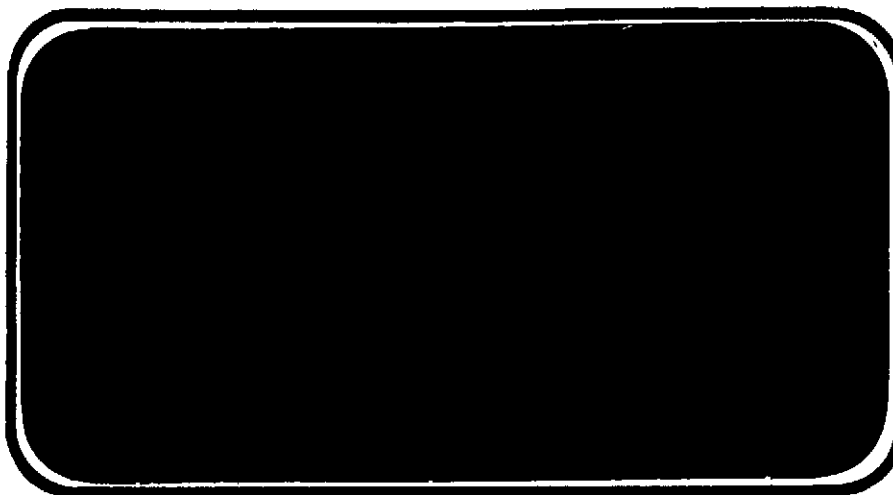




# NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA CR

141508



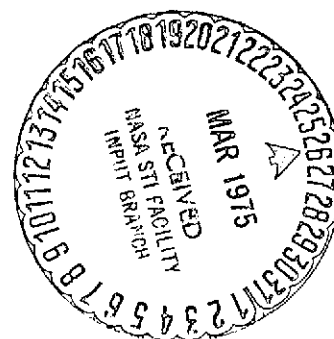
(NASA-CR-141508) RESULTS OF  
FLOW-VISUALIZATION INVESTIGATIONS ON A  
0.015-SCALE MODIFIED CONFIGURATION 140A/B  
SPACE SHUTTLE VEHICLE ORBITER (MODEL 36-0)  
IN THE LANGLEY RESEARCH CENTER 8-FOOT

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SPACE SHUTTLE

AEROTHERMODYNAMIC DATA REPORT



JOHNSON SPACE CENTER

HOUSTON, TEXAS

DATA MANAGEMENT services

SPACE DIVISION



CHRYSLER  
CORPORATION

February, 1975

DMS-DR-2229  
NASA-CR-141,508

RESULTS OF FLOW-VISUALIZATION INVESTIGATIONS ON A  
0.015-SCALE MODIFIED CONFIGURATION 140A/B  
SPACE SHUTTLE VEHICLE ORBITER (MODEL 36-0)  
IN THE LANGLEY RESEARCH CENTER  
8-FOOT TRANSONIC PRESSURE TUNNEL (0A102)

By

M. E. Nichols  
Shuttle Aero Sciences  
Rockwell International Space Division

Prepared under NASA Contract Number NAS9-13247

By

Data Management Services  
Chrysler Corporation Space Division  
New Orleans, La. 70189

for

Engineering Analysis Division

Johnson Space Center  
National Aeronautics and Space Administration  
Houston, Texas

WIND TUNNEL TEST SPECIFICS:

Test Number: LaRC 8 TPT 687  
NASA Series Number: OA102  
Model Number: 36-0  
Test Dates: 17 through 18 June 1974  
Occupancy Hours: 18

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Chrysler Corporation Space Division assumes no responsibility for  
the data other than display characteristics.

RESULTS OF FLOW-VISUALIZATION INVESTIGATIONS ON A  
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SPACE SHUTTLE VEHICLE ORBITER (MODEL 36-0)  
IN THE LANGLEY RESEARCH CENTER  
8-FOOT TRANSONIC PRESSURE TUNNEL (OA102)

By

M. E. Nichols, Rockwell International Space Division

ABSTRACT

This report details the results of a flow-visualization wind tunnel test of a 0.015-scale model of the Modified Configuration 140A/B Space Shuttle Vehicle Orbiter. The purpose of this test was to determine separation zones, flow-recirculation regions, and potential venting and contaminant-ingestion problem areas. This study was carried out by means of photographic (video tape) analysis of model-mounted tufts.

The test was conducted from 17 through 18 June 1974 during 18 test hours. It was identified as SSV Test OA102.

The model was tested at Mach numbers of 0.60, 0.90, 1.05, and 1.20, at Reynolds numbers of 3.17, 3.98, 4.16, and 4.23, respectively. Model angle-of-attack was varied from 0° to 20° at 0° sideslip-angle.

Three control-surface deflection combinations were tested. No configuration-buildup or alternate-configuration program was carried out.

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## TABLE OF CONTENTS

	Page
ABSTRACT	iii
INDEX OF MODEL FIGURES	2
NOMENCLATURE	3
CONFIGURATIONS INVESTIGATED	4
INSTRUMENTATION	6
TEST FACILITY DESCRIPTION	8
DISCUSSION OF RESULTS	9
TABLES	
I. TEST CONDITIONS	10
II. DATA SET/RUN NUMBER COLLATION SUMMARY	11
III. MODEL DIMENSIONAL DATA	12
FIGURES	20

## INDEX OF MODEL FIGURES

Figure	Title	Page
1.	Axis Systems.	20
2.	General Orbiter Configuration.	21

NOMENCLATURE  
General

<u>SYMBOL</u>	<u>SADSAC SYMBOL</u>	<u>DEFINITION</u>
a		speed of sound; m/sec, ft/sec
C <sub>p</sub>	CP	pressure coefficient; $(p_1 - p_\infty)/q$
M	MACH	Mach number; $V/a$
p		pressure; N/m <sup>2</sup> , psf
q	Q(NSM) Q(PSF)	dynamic pressure; $1/2\rho V^2$ , N/m <sup>2</sup> , psf
RN/L	RN/L	unit Reynolds number; per m, per ft
V		velocity; m/sec, ft/sec
$\alpha$	ALPHA	angle of attack, degrees
$\beta$	BETA	angle of sideslip, degrees
$\psi$	PSI	angle of yaw, degrees
$\phi$	PHI	angle of roll, degrees
$\rho$		mass density; kg/m <sup>3</sup> , slugs/ft <sup>3</sup>

Reference & C.G. Definitions

A <sub>b</sub>		base area; m <sup>2</sup> , ft <sup>2</sup>
b	BREF	wing span or reference span; m, ft
c.g.		center of gravity
$\frac{l}{c}$ <sub>REF</sub>	LREF	reference length or wing mean aerodynamic chord; m, ft
S	SREF	wing area or reference area; m <sup>2</sup> , ft <sup>2</sup>
	MRP	moment reference point
	XMRP	moment reference point on X axis
	YMRP	moment reference point on Y axis
	ZMRP	moment reference point on Z axis

SUBSCRIPTS

b	base
l	local
s	static conditions
t	total conditions
$\infty$	free stream



## CONFIGURATIONS INVESTIGATED

The 0.015-scale Rockwell International SSV Orbiter model was built to configuration control drawings VL70-000140A and VL70-000140B as combined per model drawing BD-SS-A00130 to define the "140A/B" configuration. The OMS/RCS pods were modified to conform with proposed Vehicle 5 specifications.

The model (Model 36-0) was constructed of Armco 17-4 stainless steel to meet test safety-factors of 5 based on ultimate strength and 3 based on yield strength.

The model was mounted on a sting and sting-to-model adaptor assembly. No balance or other force or moment instrumentation was employed. Tufts were arranged at prescribed locations on the Orbiter fuselage, wings, and vertical tail, as specified below.

The elevons, bodyflap, and speedbrake/rudder assembly were capable of deflections as shown in Table II.

<u>Component</u>	<u>Description</u>
B <sub>26</sub>	Orbiter fuselage per Rockwell International lines drawings VL70-000140A/B, VL70-000143, VL70-000135, VL70-000200, VL70-000205, VL70-006089, model drawing SS-A00142
C <sub>9</sub>	Orbiter canopy per Rockwell International lines drawing VL70-000140A/B, model drawing SS-A00142
E <sub>26</sub>	Orbiter full-span, unswept-hingeline, non-gapped elevons per Rockwell International lines drawings VL70-000200, VL70-006089, VL70-006092, model drawing SS-A01235
F <sub>8</sub>	Orbiter bodyflap per Rockwell International lines drawings VL70-70-000140A, VL70-000145, model drawing SS-A01236
M <sub>16</sub>	Orbiter OMS/RCS pods per Rockwell International lines study drawings VL70-008410, VL70-008410, VL70-008457 (17 May 1974).

# CONFIGURATIONS INVESTIGATED (Concluded)

- R<sub>5</sub> Orbiter rudder per Rockwell International lines drawings VL70-000146A, VL70-0000095, model drawing SS-A00143
- V<sub>8</sub> Orbiter centerline vertical tail per Rockwell International lines drawing VL70-000146A, model drawing SS-A00143
- W<sub>116</sub> Orbiter double-delta wing per Rockwell International lines drawings VL70-000200, VL70-000200, VL70-000143, model drawings SS-A00130, SS-A00143, SS-A01235

## INSTRUMENTATION

No model force or moment data or pressures were obtained. Tunnel pressure data were measured for computing the usual tunnel parameters. Model angle-of-attack was also determined.

Rows of nylon tufts were attached to the model at the locations given below:

1. Tufts around the fuselage at these model stations:

<u>Row #</u>	<u>Station</u>
1	4.25
2	8.10
3	10.05
4	12.00
5	15.00
6	18.00
7	21.75

2. Tufts on top and bottom of both wings:

<u>Row #</u>	<u>% Chord</u>
8	15
9	50
10	90

3. Tufts on both sides of the vertical tail:

<u>Row #</u>	<u>% Chord</u>
11	15
12	50
13	90

4. Tufts were also mounted on a rake-post arrangement aft of the vertical tail at a distance of one inch from the trailing edge. This was identified as Row #14.

## INSTRUMENTATION (Concluded)

Tufts were approximately 3/4-inch long and were spaced approximately 3/4-inch apart in their rows at the locations specified above.

## TEST FACILITY DESCRIPTION

The NASA/Langley Research Center 8-Foot Transonic Pressure Tunnel is an air-medium, single-return, closed-circuit facility with the capability of continuous Mach number variation from 0.2 to 1.3. Stagnation temperature and pressure and dewpoint temperature are controlled. Reynolds number is variable from  $0.3 \times 10^6/\text{ft}$  to  $7.0 \times 10^6/\text{ft}$ , depending on Mach number.

Models are supported in the 7.1-foot-square test section by means of stings attached to the tunnel sector system. Wall mounts are also available for airfoil-type testing.

## DISCUSSION OF RESULTS

The test program involved only videotape recording of tuft behavior on the Orbiter fuselage and upper and lower wing regions. The tape quality and resolution were sufficient for on-site and later off-site visual analysis, but the tapes did not lend themselves well to still-photographic reproduction for presentation here.

Extensive review of the tapes showed that the local flow directions on the aft fuselage, as affected by the late-design, shorter OMS pods, were clearly delineated by the tufts during transonic conditions. No reverse-flow, forward-traveling patterns were apparent. Concern about unusual flow from the base region forward along the fuselage (possibly even as far as the nose/canopy area) was alleviated.

Clear delineation of vortex and boundary-layer separation regions on the fuselage and wing surfaces was apparent. The transonic capabilities of tuft-analysis were affirmed. Videotape recording also allowed study of early flow-development patterns, as well as transitions during attitude change.

The videotape-form data will be retained by Rockwell International Space Division Aerodynamics personnel for future reference and study.

TABLE I.

[illegible]

TABLE II.

[illegible]

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TABLE III. - MODEL DIMENSIONAL DATA

MODEL COMPONENT : BODY - B<sub>26</sub>

GENERAL DESCRIPTION : Configuration 140A/B Orbiter Fuselage

NOTE: B<sub>26</sub> is identical to B<sub>24</sub> except underside of fuselage has been  
refaired to accept W<sub>116</sub>.

MODEL SCALE: 0.015 MODEL DRAWING: SS-A00147, RELEASE 12

DRAWING NUMBER VL70-000143B, -000200, 000205, -006089, -000145,  
-000140A, 000140B

DIMENSIONS :	FULL SCALE	MODEL SCALE
*Length (OML: Fwd Sta. X <sub>0</sub> =235)-In.	1293.3	19.400
*Length (IML: Fwd Sta. X <sub>0</sub> =238)-In.	1290.3	19.350
* Max Width (@ X = 1528.3) - In.	264.0	3.960
Max Depth (@ X <sub>0</sub> = 1464) - In.	250.0	3.750
Fineness Ratio		
Area - Ft <sup>2</sup>		
Max. Cross-Sectional	340.88	0.077
Planform		
Wetted		
Base		

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : CANOPY - C<sub>9</sub>

GENERAL DESCRIPTION : Configuration 3A, Canopy used with Fuselage

B<sub>26</sub>

MODEL SCALE: 0.015 MODEL DRAWING: SS-A00147, RELEASE 12

DRAWING NUMBER VL70-000143A

DIMENSIONS :	FULL SCALE	MODEL SCALE
* Length ( $X_0 = 434.643$ to $578$ )	<u>143.357</u>	<u>2.150</u>
Max Width (@ $X_0 = 513.127$ )	<u>152.412</u>	<u>2.286</u>
Max Depth (@ $X_0 = 485.0$ )	<u>25.000</u>	<u>0.375</u>
Fineness Ratio	<u>                    </u>	<u>                    </u>
Area	<u>                    </u>	<u>                    </u>
Max. Cross-Sectional	<u>                    </u>	<u>                    </u>
Planform	<u>                    </u>	<u>                    </u>
Wetted	<u>                    </u>	<u>                    </u>
Base	<u>                    </u>	<u>                    </u>

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: ELEVON - E<sub>26</sub>GENERAL DESCRIPTION: Configuration 140A/B Orbiter ElevonsDATA ARE FOR ONE SIDE.MODEL SCALE: 0.015MODEL DRAWING: SS-A00148, RELEASE 6DRAWING NUMBER:VL70-000200, -006089, -006092DIMENSIONS:FULL-SCALEMODEL SCALE

Area $\text{Ft}^2$	<u>210.0</u>	<u>0.0473</u>
Span (equivalent) - In.	<u>349.2</u>	<u>5.238</u>
Inb'd equivalent chord - In.	<u>118.004</u>	<u>1.770</u>
Outb'd equivalent chord - In.	<u>55.192</u>	<u>0.828</u>
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	<u>0.2096</u>	<u>0.2096</u>
At Outb'd equiv. chord	<u>0.4004</u>	<u>0.4004</u>
Sweep Back Angles, degrees		
Leading Edge	<u>0.00</u>	<u>0.00</u>
Trailing Edge	<u>- 10.056</u>	<u>- 10.056</u>
Hingeline	<u>0.00</u>	<u>0.00</u>
* Area Moment (Product of Area & $\bar{c}$ ) - $\text{Ft}^3$	<u>1587.25</u>	<u>0.0054</u>
*Mean Aerodynamic Chord - In.	<u>90.7</u>	<u>1.361</u>

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : BODY FLAP - F<sub>0</sub>

GENERAL DESCRIPTION : Configuration 140A/B orbiter body flap.

Hingeline located at X<sub>0</sub> = 1528.3, Z<sub>0</sub> = 284.3

MODEL SCALE: 0.015 MODEL DRAWING: SS-A00147, RELEASE 12

DRAWING NUMBER: VI70-000140A, VI70-000145

DIMENSIONS :	FULL SCALE	MODEL SCALE
Length (X <sub>0</sub> =1520 to X <sub>0</sub> =1613), In.	<u>93.00</u>	<u>1.395</u>
Max Width , In.	<u>262.00</u>	<u>3.930</u>
Max Depth (X = 1520), In.	<u>23.00</u>	<u>0.345</u>
Fineness Ratio	<u>          </u>	<u>          </u>
Area - Ft <sup>2</sup>	<u>          </u>	<u>          </u>
Max. Cross-Sectional	<u>          </u>	<u>          </u>
Planform	<u>150.525</u>	<u>0.0339</u>
Wetted	<u>          </u>	<u>          </u>
Base	<u>41.84722</u>	<u>0.0010</u>

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT : OMS POD - M<sub>16</sub>

GENERAL DESCRIPTION : Configuration 140C orbiter OMS pod - short  
pod.

MODEL SCALE: 0.015

DRAWING NUMBER : VL70-008401, VL70-008410

DIMENSIONS :	FULL SCALE	MODEL SCALE
Length (OMS Fwd Sta $X_0=1310.5$ ), In.	<u>258.50</u>	<u>3.878</u>
Max Width (@ $X_0 = 1511$ ), In.	<u>136.8</u>	<u>2.052</u>
Max Depth (@ $X_0 = 1511$ ), In.	<u>74.70</u>	<u>1.121</u>
Fineness Ratio	<u>2.484</u>	<u>2.484</u>
Area - Ft <sup>2</sup>	<u>          </u>	<u>          </u>
Max. Cross-Sectional	<u>58.865</u>	<u>0.0132</u>
Planform	<u>          </u>	<u>          </u>
Wetted	<u>          </u>	<u>          </u>
Base	<u>          </u>	<u>          </u>

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: RUDDER - R<sub>5</sub>GENERAL DESCRIPTION: 2A, 3, 3A and 140A/B ConfigurationsMODEL SCALE: 0.015DRAWING NUMBER: VL70-000146A, VL70-000095, VL70-000139.

<u>DIMENSIONS:</u>	<u>FULL-SCALE</u>	<u>MODEL SCALE</u>
*Area- Ft <sup>2</sup>	<u>100.15</u>	<u>0.0225</u>
Span (equivalent) - In	<u>201.0</u>	<u>3.015</u>
Inb'd equivalent chord - In.	<u>91.585</u>	<u>1.3738</u>
Outb'd equivalent chord - In.	<u>50.833</u>	<u>0.7625</u>
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	<u>0.400</u>	<u>0.400</u>
At Outb'd equiv. chord	<u>0.400</u>	<u>0.400</u>
Sweep Back Angles, degrees		
Leading Edge	<u>34.83</u>	<u>34.83</u>
Trailing Edge	<u>26.25</u>	<u>26.25</u>
Hingeline	<u>34.83</u>	<u>34.83</u>
* Area Moment (Product of area & $\bar{c}$ )-Ft <sup>3</sup>	<u>610.92</u>	<u>0.002</u>
*Mean Aerodynamic Chord, In.	<u>73.2</u>	<u>1.098</u>

TABLE III. - MODEL DIMENSIONAL DATA - Continued.

MODEL COMPONENT: VERTICAL - V<sub>8</sub>GENERAL DESCRIPTION: Configuration 140A/B Orbiter Vertical TailMODEL SCALE: 0.015MODEL DRAWING: SS-A00148, RELEASE 6DRAWING NUMBER: VL70-000146ADIMENSIONS: FULL SCALE MODEL SCALE

## TOTAL DATA

Area (Theo) - Ft <sup>2</sup>		
Planform	<u>413.253</u>	<u>0.093</u>
Span (Theo) - In.	<u>315.720</u>	<u>4.736</u>
Aspect Ratio	<u>1.675</u>	<u>1.675</u>
Rate of Taper	<u>0.507</u>	<u>0.507</u>
Taper Ratio	<u>0.404</u>	<u>0.404</u>
Sweep-Back Angles, Degrees.		
Leading Edge	<u>45.000</u>	<u>45.000</u>
* Trailing Edge	<u>26.2</u>	<u>26.2</u>
0.25 Element Line	<u>41.130</u>	<u>41.130</u>
Chords:		
Root (Theo) WP	<u>268.500</u>	<u>4.028</u>
Tip (Theo) WP	<u>108.470</u>	<u>1.627</u>
MAC	<u>199.808</u>	<u>2.997</u>
Fus. Sta. of .25 MAC	<u>1463.50</u>	<u>21.953</u>
W.P. of .25 MAC	<u>635.522</u>	<u>9.533</u>
B.L. of .25 MAC	<u>0.00</u>	<u>0.00</u>
Airfoil Section		
Leading Wedge Angle - Deg.	<u>10.00</u>	<u>10.00</u>
Trailing Wedge Angle - Deg.	<u>14.920</u>	<u>14.920</u>
Leading Edge Radius	<u>2.00</u>	<u>0.030</u>
Void Area	<u>13.17</u>	<u>0.003</u>
Blanketed Area	<u>0.00</u>	<u>0.00</u>

TABLE III.-MODEL DIMENSIONAL DATA--CONCLUDED.

MODEL COMPONENT: WING-W<sub>116</sub>GENERAL DESCRIPTION: Configuration 4NOTE: Identical to W<sub>114</sub> except airfoil thickness. Dihedral angle is along trailing edge of wing.MODEL SCALE: 0.015

TEST NO.

DWG. NO. VL70-000140A, -000200

DIMENSIONS:

FULL-SCALE

MODEL SCALE

## TOTAL DATA

Area (Theo.)  $\text{Ft}^2$ 

Planform

Span (Theo) In.

Aspect Ratio

Rate of Taper

Taper Ratio

Dihedral Angle, degrees

Incidence Angle, degrees

Aerodynamic Twist, degrees

Sweep Back Angles, degrees

Leading Edge

Trailing Edge

0.25 Element Line

Chords:

Root (Theo) B.P.O.O.

Tip, (Theo) B.P.

MAC

\*Fus. Sta. of .25 MAC

\*W.P. of .25 MAC

\*B.L. of .25 MAC

## EXPOSED DATA

\* Area (Theo)  $\text{Ft}^2$ 

\* Span, (Theo) In. BP108

\* Aspect Ratio

Taper Ratio

Chords

\* Root BP108

Tip 1.00  $\frac{b}{2}$ 

\* MAC

\* Fus. Sta. of .25 MAC

\* W.P. of .25 MAC

\* B.L. of .25 MAC

Airfoil Section (Rockwell Mod NASA)

XXXX-64

Root  $\frac{b}{2}$  =Tip  $\frac{b}{2}$  =

Data for (1) of (2) Sides

Leading Edge Cuff

\*Planform Area  $\text{Ft}^2$ 

\* Leading Edge Intersects Fus M. L. @ Sta

\* Leading Edge Intersects Wing @ Sta

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### Notes:

1. Positive directions of force coefficients, moment coefficients, and angles are indicated by arrows
2. For clarity, origins of wind and stability axes have been displaced from the center of gravity

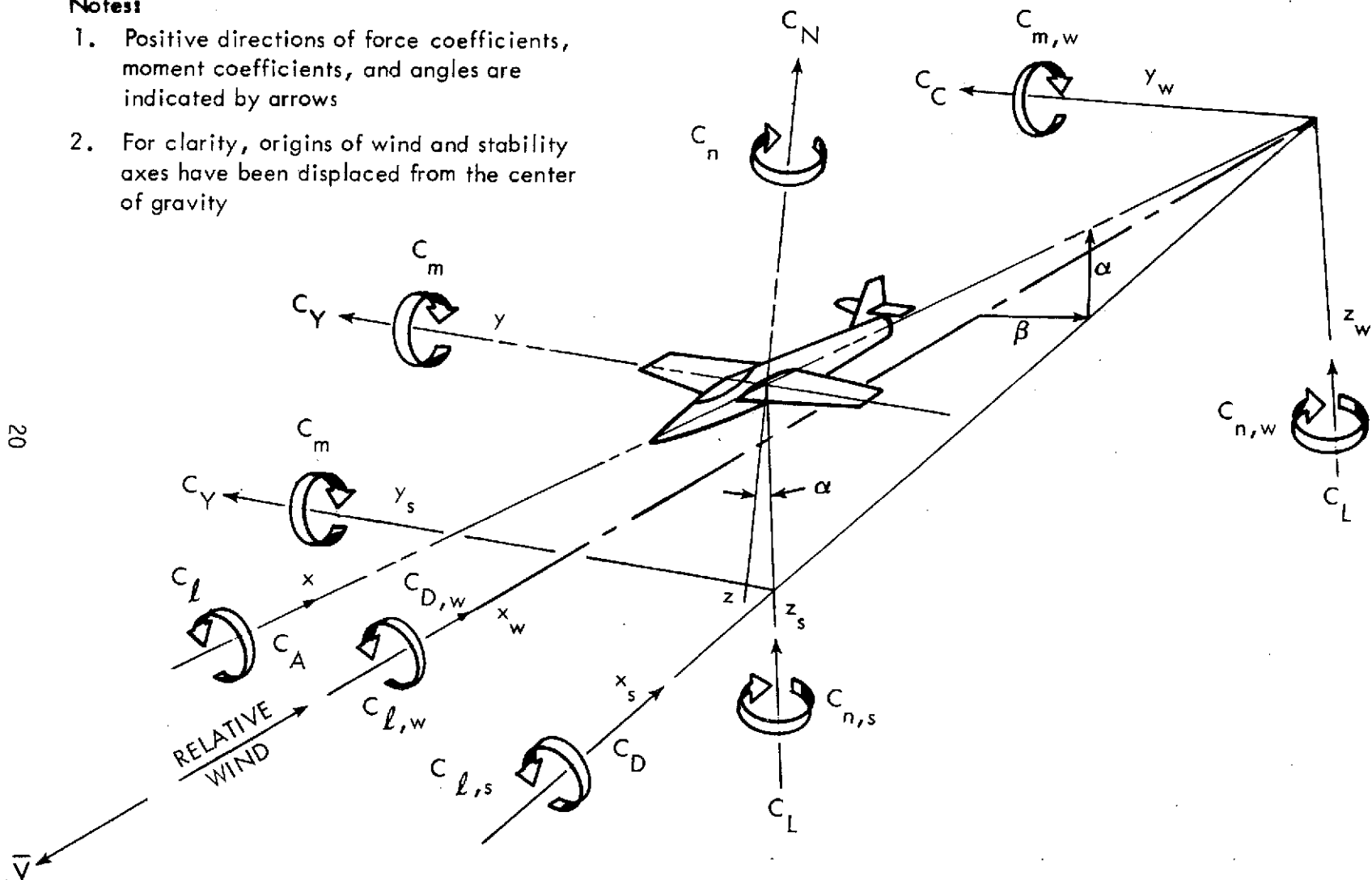


Figure 1. Axis Systems

CONFIGURATION: B26C9F8M16V8R5W116E26

$Y_o = 311.0$  (GAPS NOT SIMULATED)

(MPS NOZZLES NOT SIMULATED)

DIMENSIONS FULL SCALE

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21

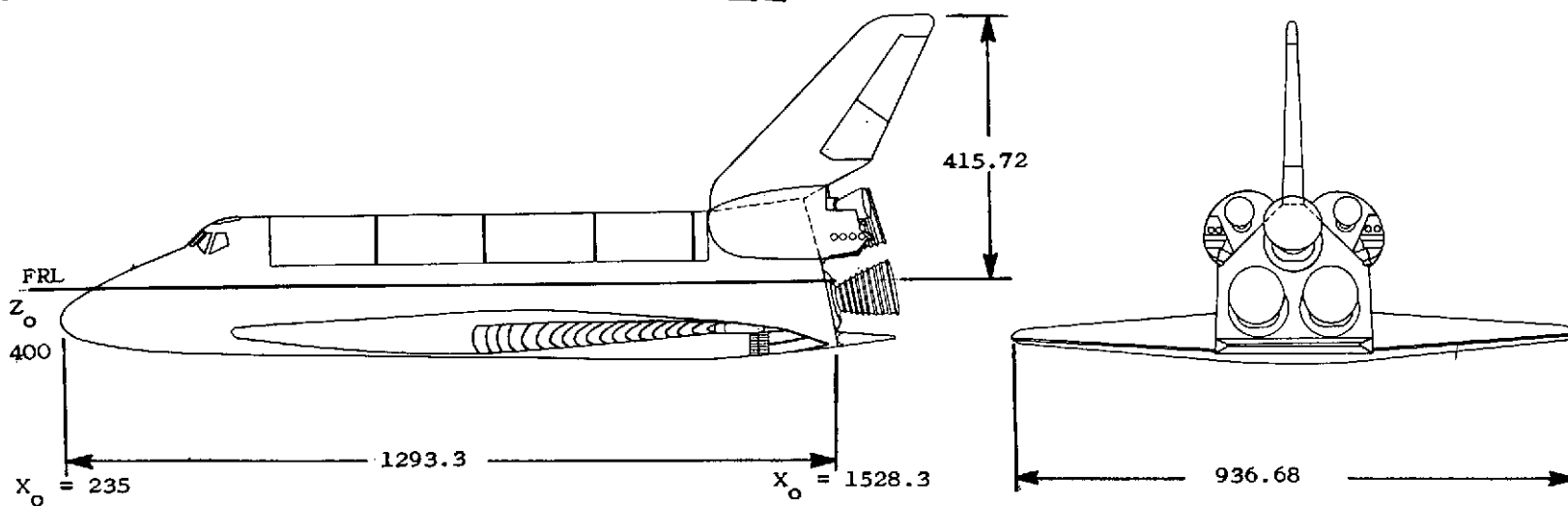


Figure 2. - General Orbiter Configuration.